SF 298 MASTER COPY . KEEP THIS COPY FOR REPRODUCTION PURPOSES

REPORT DOCUMENTATION PAGE	Form Approved OMB NO. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comment regarding this burden estimates or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 1, 1997	Final Progress Report 11/01/94-10/31/95

4. TITLE AND SUBTITLE

"Instrumentation in Support of Interactive Visualization, Computation and Simulation"

5. FUNDING NUMBERS

DAAH04-95-1-0009

6. AUTHOR(S)

Edward J. Wegman

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES)

Center for Computational Statistics
George Mason University
Fairfax, VA 22030

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

ARO 33720.1-MA-RIP

11. SUPPLEMENTARY NOTES

The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12 b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This research accomplished as a result of this effort focused on the alliance of elements of virtual reality technology and elements of scientific visualization to address issues of mine-dection and related spatial and volumetric visualization problems.By virtual environments, we meant an immersive visual and audio technology such that experimenter has little or no awareness of the real environment. For our purposes of data visualization, this was intended as a focusing devise so that the experimenter has a heightend sense of awareness of the problem at hand thus, can concentrate in a natural way his or her full mental resources. Much of currently fashionable work on scientific visualization had been focused on rendering on flow fields arising from combustion or meteorological applications, molecular, atomic or subatomic particle dynamics, and other settings modeled with partial differential equation models. Our focus had been, in contrast, or data representation, exploratory data analysis and model building using high performance computer graphics, much of which has recently emerged under the name **data mining.**

DTIC QUALITY INSPECTED 4

14. SUBJECT TERMS

Virtual Reality, head mounted display system, stereoscopic projection, texture map engine, spatial and volumetric visualization, scientific visualization, data mining

15. NUMBER IF PAGES

6

16. PRICE CODE

17. SECURITY CLASSIFICATION OR REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Instrumentation in Support of Interactive Visualization, Computation, and Simulation

Center for Computational Statistics
George Mason University

Performance Period: 1 November 1994 to 31 October 1995

Proposal Number: P-33720-MA-RIP
Contract Number: DAAH04-95-1-0009

Edward J. Wegman

Final Report

19970820 067

Introduction

This effort was based on a proposal to upgrade existing virtual reality and supercomputing facilities at George Mason University. The virtual reality facilities at the Center for Computational Statistics at George Mason University had been under active development for just over 22 months. The computer suite used at the time directly in support of the virtual environments facility includes a Silicon Graphics Power Series 4D/120/GTX, a Silicon Graphics Indigo R4000 Elan and a Silicon Graphics Crimson VGXT which had proven inadequate for the VR visualization requirements. The highest performance graphics engine was then the VGXT engine in our SGI Crimson.

The virtual reality laboratory also contained a head mounted display system by Virtual Research, Inc. The position sensing of both head and hand is accomplished with Ascension Technology's Flock of Birds Sensors. The conversion from RGB high resolution computer display to NTSC was accomplished with a two channel encoder/decoder. The setup we had prior to this award required the use of a Crimson VGXT for one eye and the Indigo Elan for the other. This was a severe mismatch in terms of both speed and graphics capability. We proposed to correct this and upgrade our graphics capability by acquiring a SGI Onyx RE^2. This in fact has been accomplished. We had also installed a Stereographics high resolution projection system. It is driven by the SGI machines and is capable of stereoscopic projection using Stereographics' Crystal Eyes technology. We own seven Crystal Eyes' active stereo glasses including one which contains an acoustic position sensor.

We have had long experience with parallel computing (since 1987). We currently operate an Intel iPSC/2 d4/VX concurrent computer with 16 compute nodes capable of approximately 320 megaflops peak speed. We took delivery of an Intel Paragon XP/S A4 concurrent computer with 61 compute nodes capable of a peak speed of 4.2 gigaflops. The Paragon was installed on January 12, 1994. Both of these machines will be tied into the virtual reality labs, and as outlined in the proposal, we expected to use these machines as compute engines for our virtual environments research.

We specifically had proposed to acquire several pieces of equipment:

1. A Silicon Graphics Onyx workstation with RE^2 graphics, multiple CPUs, and a HiPPI[1] channel.

2. A HiPPI channel i/o board for the Intel Paragon.

3. Equipment to translate HiPPI to fiber optics and back.

4. The installation of fiber optic cable between buildings. This will be cost matching by the University.

1

The Silicon Graphics Onyx was the latest of the SGI workstation platforms. It uses the R4400 64-bit processor running at 150 megahertz which makes the workstation more than three times as fast as our current Crimson workstation. Our then current capabilities were limited by not only CPU speed, but also graphics rendering speed. The VGXT graphics engine in our Crimson is an extremely capable texture map engine. However, on current simulation tasks with texture mapping, the machine was capable of only about 10 frames a second. The motion is not smooth or realistic. The addition of the new CPUs together with the RE^2 rendering engines should deliver at least 30 frames per second high resolution video.

The Silicon Graphics Onyx with RE^2 graphics engine was acquired as planned. Regrettably, the University was in the process of building a new network infrastructure and, because of serious delays, the fiber optic cabling was not installed as planned. The money originally planned for the HiPPI-channel upgrade was rerouted to an upgrade of the SGI machine. The SGI Onyx has proven to be an extremely robust performer and has satisfied the immediate needs for speed upgrade. At this writing it has been superseded by even faster machines, but it should be effective in our research for the next several years.

Research Efforts

This research accomplished as a result of this effort focused on the alliance of elements of virtual reality technology and elements of scientific visualization to address issues of mine detection and related spatial and volumetric visualization problems. By virtual reality or virtual environments, we meant an immersive visual and audio technology such that experimenter has little or no awareness of the real environment. For our purposes of data visualization, this was intended as a focusing device so that the experimenter has a heightened sense of awareness of the problem at hand and, thus, can concentrate in a natural way his or her full mental resources. Much of currently fashionable work on scientific visualization had been focused on rendering of flow fields arising from combustion or meteorological applications, molecular, atomic or subatomic particle dynamics, and other settings modeled with partial differential equation models. Our focus had been, in contrast, on data representation, exploratory data analysis and model building using high performance computer graphics, much of which has recently emerged under the name *data mining*.

Mine Countermeasures. Underwater mines and land mines represent an insidious threat to military personnel and equipment. They are usually relatively inexpensive devices that can cause serious losses both in terms of human life and limb as well as capital assets. Moreover, even to those not injured, mines represent a demoralizing factor to the forces because of their surreptitious nature. Thus, mine warfare levels the playing field in the sense that even technologically superior forces can succumb to the effects of mine warfare. For all of these reasons, mine warfare is a favored device for all potential adversaries, both those that are technologically sophisticated and especially those less technologically sophisticated. Thus the detection of mines with a high degree of confidence can remove potential vulnerability to and, perhaps more importantly, a sense of vulnerability to these devices.

For purposes of data input, we assumed imaging sensors with one or more imaging technologies available. For example, in the spatial problem of interest to the Army, we expect that a number of multispectral channels, say up to eight, would be available. These would be spectral channels ranging from near infrared to near ultraviolet. Thus even mines camouflaged in the visible spectrum are likely to be quite detectable by discriminating on their spectral characteristics. The integration of all of these sensor images by one or more of the techniques we proposed and the display of the resultant image with an immersive technology yields a tool for our forces that should allow them to confidently navigate mine fields.

Virtual Reality, Immersive Technology and Scientific Visualization. The development of virtual reality as a graphics construct began in the mid-seventies with attempts to develop more realistic flight simulation. The standard paradigm was to have training pilots look at a visual display screen. The effect, as might be expected, was that these pilots were aware that they were looking at a visual display screen and, consequently, had a comparatively strong sense of unreality about the whole exercise. An approach to overcoming this problem has become known as *virtual reality.* The intent of the virtual reality construct is to create a more intimate sense of involvement (originally in the flight simulation), i.e. a sense of immersion. Virtual reality constructs can be implemented in several ways. The major new thrust in statistical data analysis and visualization is to combine scientific visualization, exploratory data analysis and virtual reality into a new technology for exploring data.

Visualization using the Grand Tour. In much of the work on visualization for data analysis, spatial extension is considered only as an abstract representation of a data variable, but not as any real entity. Although we had been (and still are) interested in representation and visualization of multivariate data, it is clear then there are many circumstances in which it is appropriate to measure variables in a spatial or volumetric setting. Consider, for example, the setting in which we take images of a minefield in eight spectral bands. This is an example of spatially extended multivariate data. At each pixel location, we have eight-dimensional multivariate data corresponding to the intensity levels of light in each of the eight spectral channels. A minefield may be two-dimensionally extended (spatially extended) in the case of land mines or may be three-dimensionally extended (volumetrically extended) in the case of underwater mines. Here we are concerned with a truly volumetric setting in which multiple sensors may give us partial tactical information about targets. Again each voxel has a multidimensional vector attached to it which may have many missing observations. This scenario extends in an obvious way to a EW electromagnetic environment as well as to potential civilian applications such as medical diagnostics.

3. Papers Published (or prepared with direct support of this machine)

Solka, J. L., Poston, W. L., and Wegman, E. J. (1995) "A new visualization technique to study the time evolution of finite and adaptive mixture estimators." ***Journal of Computational and Graphical Statistics***, 4(3), 180-198.

Wegman, E. J. (1995) "Huge data sets and the frontiers of computational feasibility," ***Journal of Computational and Graphical Statistics***, 4(4), 281-195.

Wegman, E. J., Poston, W. L., and Solka, J. L. (1995) "Immersive methods for mine warfare," ***MASERV '95: Proceedings of the Second International Conference on the Military Applications of Synthetic Environments and Virtual Reality***, 203-218.

Marchette, D. J., Solka, J. L., Poston, W. L., and Wegman, E. J. (1996) "Visualization of adaptive mixtures estimates of DNA flow cytometry data," ***Computing Science and Statistics***, 27, 447-455

Wegman, E. J. and Luo, Q. (1997) "Visualizing densities," to appear, ***Journal of Computational and Graphical Statistics***

Carr, D. B. and Olsen, A. R., Representing Cumulative Distributions with Parallel Coordinate Plots, August, 1995, Technical Report 115, Center for Computational Statistics, George Mason University

Solka, Jeffrey, L. ***Matching Model Information Content to Data Information*** (Ph.D. Dissertation), August, 1995, Technical Report 116, Center for Computational Statistics, George Mason University

Poston, Wendy L. ***Optimal Subset Selection Methods***, (Ph.D. Dissertation), August, 1995, Technical Report 117, Center for Computational Statistics, George Mason University

Perez-Lopez, Kathleen Golitko, ***Management of Scientific Image Databases Using Wavelets*** (Ph.D. Dissertation), August, 1995, Technical Report 122, Center for Computational Statistics, George Mason University

Wegman, E. J. and Luo, Q., High Dimensional Clustering using Parallel Coordinates and the Grand Tour, April, 1996, Technical Report 124, Center for Computational Statistics, George Mason University, to appear ***Computing Science and Statistics***

Ball, Celesta G. and Edward J. Wegman, Geometric Modeling of Vehicle Paths and Confidence Regions, May, 1996, Technical Report 127, Center for Computational Statistics, George Mason University, to appear ***Computing Science and Statistics***

Wegman, Edward J., Daniel B. Carr, R. Duane King, John J. Miller, Wendy L. Poston, Jeffrey L. Solka, and John Wallin, Statistical Software, Siftware, and Astronomy, May, 1996, Technical Report 128, Center for Computational Statistics, George Mason University, to appear ***Statistical Methods for Astronomy***

Minnotte, Michael, David J. Marchette, and Edward J. Wegman, The Bumpy Road to the Mode Forest, December, 1996, Technical Report 129, Center for Computational Statistics, George Mason University, to appear ***Journal of Computational and Graphical Statistics***

Wei, Shumei, ***Image Noise Reduction using Wavelets***, (Ph.D. Dissertation), January, 1997, Technical Report 134, Center for Computational Statistics, George Mason University

Marchette, David J. ***The Filtered Kernel Density Estimator***, (Ph.D. Dissertation), January, 1997, Technical Report 135, Center for Computational Statistics, George Mason University

Faxon, Don R. ***Computational Algorithm for Generalized Nonparametric Function Estimation***, (Ph.D. Dissertation), January, 1997, Technical Report 136, Center for Computational Statistics, George Mason University

4. Students and Faculty Supported with this Grant

This award was a DURIP instrumentation award. The money was directly spent on equipment. However, numerous students and faculty have been supported via this equipment. Faculty include Edward J. Wegman, Daniel B. Carr, Menas Kafatos, Jim X. Chen, Behrouz Aghevli, John Miller, John Wallin, . Students include Wendy L. Poston (Ph.D., 1995), Jeffrey L. Solka (Ph.D., 1995), David J. Marchette (Ph.D., 1996), Qiang Luo (Ph.D. anticipated, 1997), Kathleen Golitko Perez-Lopez (Ph.D., 1995), Shumei Wei (Ph.D., 1997), and Don R. Faxon (Ph.D., 1997). Dr. Faxon is a retired U.S. Army officer.